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The Effect of Spindle Speed on The Surface of Teak Wood Work Pieces on A 3 Axis CNC Router Machine

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ABSTRAK

Efektivitas waktu proses pemesinan dan kualitas kekasaran permukaan merupakan faktor utama untuk evaluasi produk pemesinan dapat diterima atau tidak. kecepatan spindle salah satu cara dalam memaksimalkan waktu proses. Penelitian ini bertujuan untuk mengetahui pengaruh variasi kecepatan spindle terhadap kekasaran permukaan benda dari material kayu jati dengan menggunakan mesin CNC router 3 axis. Metode penelitian menggunakan metode eksperimen pada benda dengan material kayu jati dengan menggunakan variasi kecepatan spindle 4000, 6000, dan 8000 RPM. Kemudian dilakukan pengukuran kekasaran permukaan, dan menganalisis hasil pengukuran untuk mengetahui pengaruh dari variasi kecepatan spindle. Hasil penelitian kekasaran permukaan benda, kecepatan spindle 8000 RPM menghasilkan nilai Ra senilai 10,988 µm yang merupakan nilai Ra terendah.

ABSTRACT

The effectiveness of machining process time and surface roughness quality are the main factors for evaluating whether the machining product is acceptable or not. Spindle speed is one way to maximize process time. This study aims to determine the effect of spindle speed variations on the surface roughness of objects made of teak wood material using a 3-axis CNC router machine. The research method uses an experimental method on objects made of teak wood using spindle speed variations of 4000, 6000, and 8000 RPM. Then the surface roughness measurements were carried out, and the measurement results were analyzed to determine the effect of spindle speed variations. The results of the study on the surface roughness of objects, spindle speed 8000 RPM produced a Ra value of 10.988 µm which is the lowest Ra value.

1. INTRODUCTION

Manufacturing companies are currently faced with increasingly competitive market demands. Therefore, they are required to implement new strategies to meet these needs. The combination of price and production quality is an important factor that must be adjusted so that companies can achieve adequate profits. However, on the other hand, consumers generally expect quality products but at affordable prices. Therefore, manufacturers must be able to create quality products without sacrificing production costs. One effective strategy to reduce production costs is to minimize the time required in the product manufacturing process. This is due to the close relationship between production time and costs incurred. The longer it takes to produce a product, the higher the costs that must be borne. As a result, the selling price of the product will also increase (Hidayatulloh et al., 2020).

CNC (Computer Numerical Control) machines are one type of machine that is capable of producing goods in large quantities automatically and effectively, and producing products in a

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relatively short time (Hidayatulloh et al., 2020). CNC machines are programmed using PLCs, which function as the heart of the machine circuit. This PLC has an important role as an ON or OFF controller for input and output components, and also functions as a pulse controller (Widiyaningsih & Irwanto, 2021) In addition to PLCs, servo motors are used in robotic arms and are also used in CNC machines to move the arms on each axis (Salam et al., 2020; Subekti et al., 2025). The use of CNC machines has been done, including to make condenser surfaces using copper material (Hidayatulloh et al., 2020). CNC machines can be used with program code input where this program code can be directly inputted into the machine and also obtained from software. MasterCam is one that has been used to make hexagonal screwdriver holder molds (Nulhakim, 2017). In addition, the use of Siemens NX software to make packaging molds using aluminum material for plastic packaging (Syarifudin, Muhammad Agus Shidiq et al., 2024). In addition to being able to produce program codes, CAM software can also be used to find out whether the program is as desired by carrying out simulations, for example RenanSoft software (Diratama et al., 2024). CNC machines are used to make hexagonal screwdriver holder molds where the material used is aluminum (Nulhakim, 2017). In addition, CNC machines are used to make check fixtures using S45C steel material (Sangrila & Alam, 2019). CNC machines are also used to make drive shaft parts with 308 stainless steel material (Sopyandi & Yunus, 2022). Making bottle cap molds with aluminum-6061 material using a CNC Milling machine (Thomas et al., 2023). CNC machines in addition to being used in the cutting process can also be used as carving tools, called CNC Router machines, one of which is by using coconut wood material, the machining process is carried out with a CNC machine which produces mortar-shaped crafts (Anam et al., 2024).

In the machining process using a CNC machine, product quality is greatly influenced by the level of surface roughness produced. In addition, the effectiveness of the time required in the machining process is also an important factor in product evaluation. Thus, surface roughness and machining time are two main elements that determine whether the product is acceptable or not (Anam et al., 2024; Sangrila & Alam, 2019). So it is interesting to conduct research on the effect of speed on the surface roughness of cutting results.

2. METHOD

The implementation of this research began by first creating a design using Aspire Vetric CAD (Computer Aided Design) software according to the specified size and shape, as seen in Figure 1.

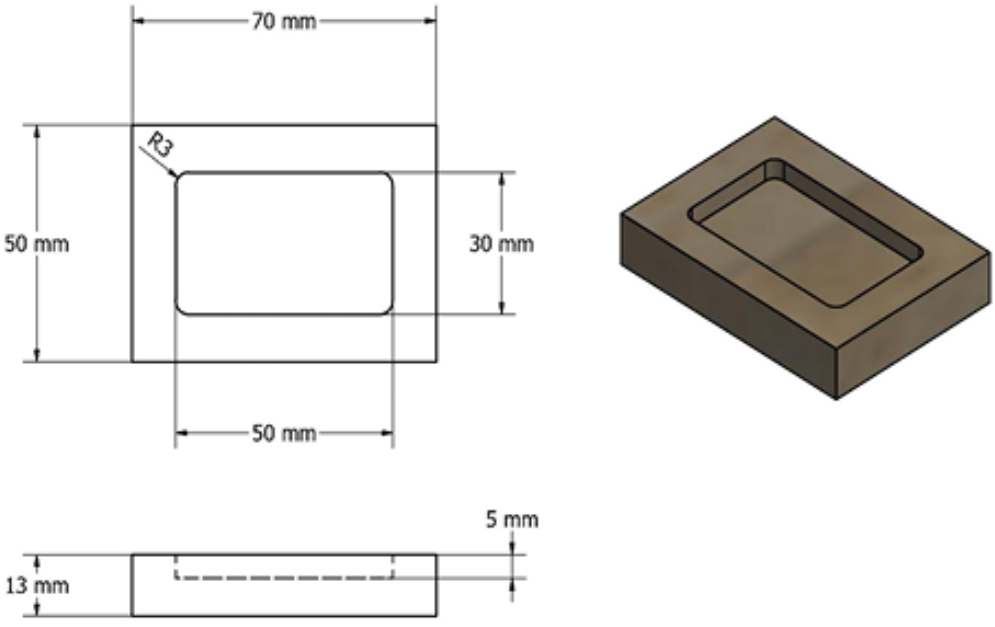

Figure 1. Workpiece Design.

The stages of the test object manufacturing process are as follows:

1. Job Setup.

The parameters entered at this stage are the first job type (the number of sides to be machined) with the single-sided option, then the job size or size of the workpiece (X, Y, and Z) with X = 50 mm, Y = 70 mm, and Z = 13 mm. After that, set the z zero position or zero position of the Z axis to the workpiece with the material surface option, and the last parameter is the XY datum position, which is the zero point of the X and Y axes on the workpiece which is used as a reference for placing and creating the design or pattern of the workpiece, as seen in Figure 2.

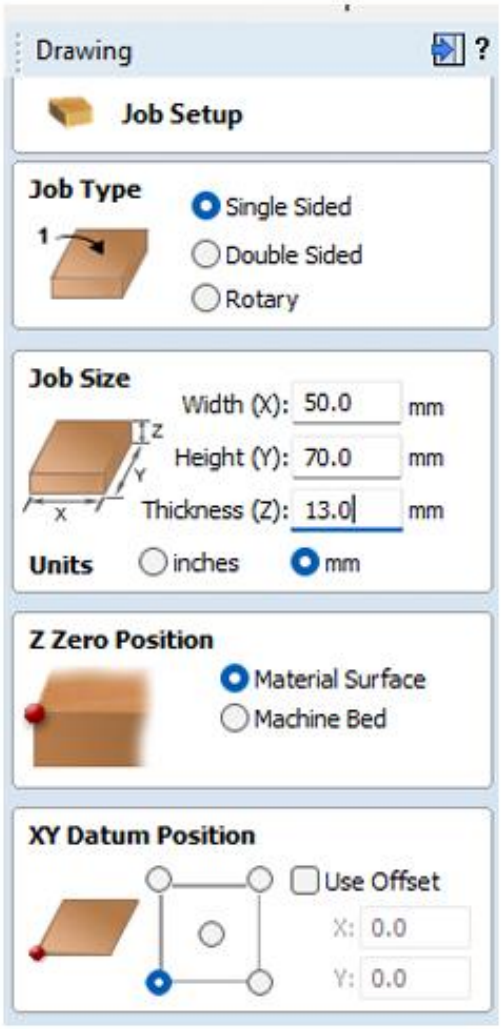

Figure 2. Job Setup Menu.

2. Drawing

In this menu, draw rectangle is selected. In this menu there are several parameters that must be inputted, the first is the anchor point (the position of the vector placement on the workpiece) with the anchor point parameter 25.0 on the X axis and 35.0 on the Y axis of the workpiece. Then the corner type parameter (Corner Shape) with the square option. The last parameter in this menu is the size of the vector created, with the width parameter 30 mm, and the height parameter 50 mm, as seen in Figure 3.

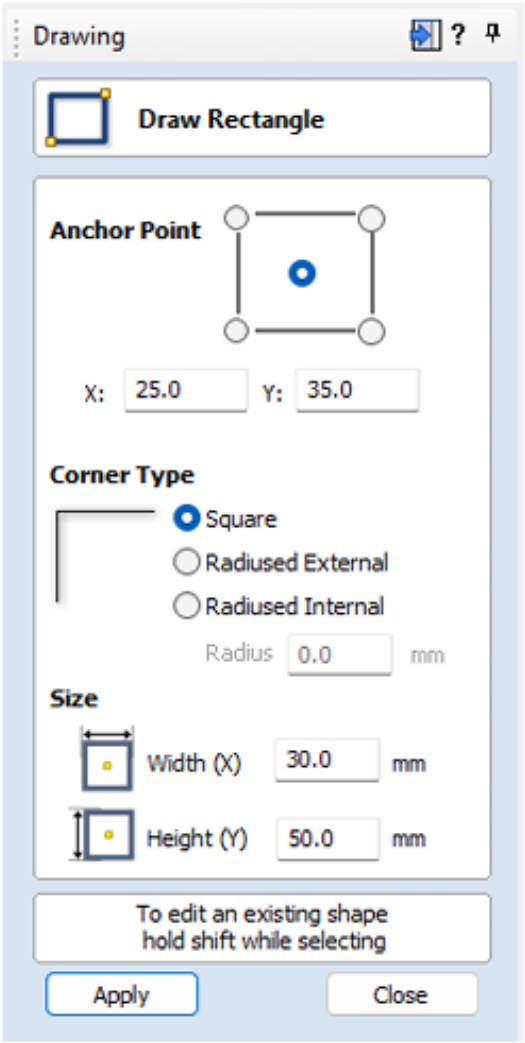

Figure 3. Draw Rectangle Menu.

3. Set Toolpath

The next step is to enter several parameters in the toolpath menu, the first is the type of toolpath operations or determining the path to be taken by the endmill. The selected option is pocket toolpath. After that, determine the size of the cutting depth, the parameters entered are the size of the start depth (D) 0.5 mm, and the cut depth (C) 5 mm, seen in Figure 4.

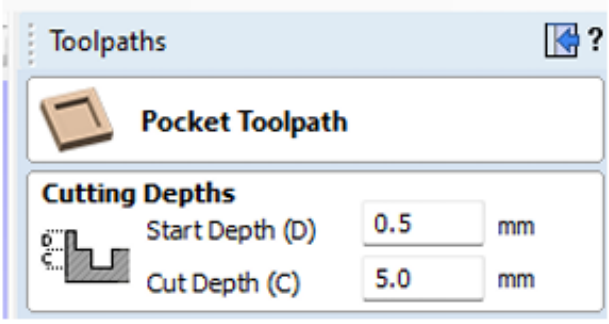

Figure 4. Toolpath Menu.

The next step is to enter several parameters in the toolpath menu, the first is the type of toolpath operations or determining the path to be taken by the endmill. The selected option is pocket toolpath. After that, determine the size of the cutting depth, the parameters entered are the size of the start depth (D) 0.5 mm, and the cut depth (C) 5 mm, seen in Figure 5.

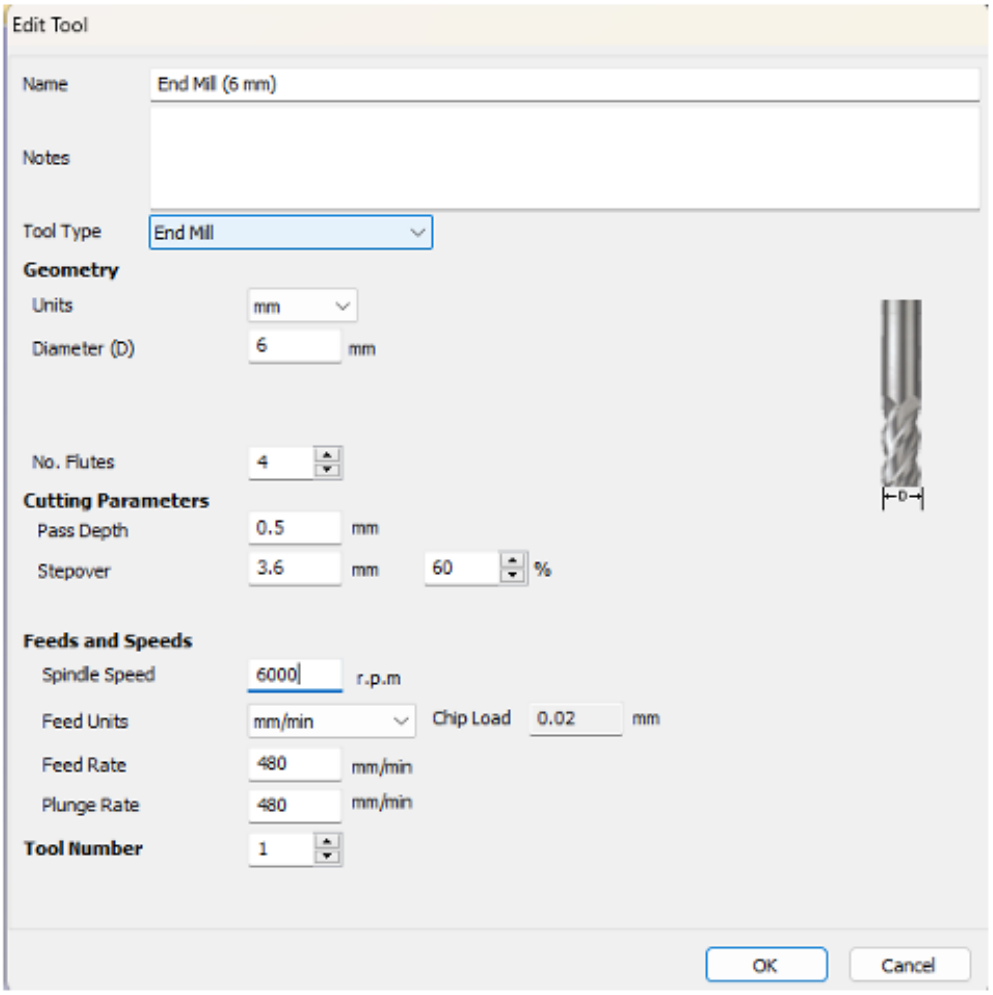

Figure 5. Cutting Tool Parameters.

4. Cutting Process

Once the CAD process is completed, the CAM process begins, which includes inputting G and M program codes into the Openbuilds Control software. This is followed by establishing the zero point of the workpiece along the X, Y, and Z axes. The final step involves cutting the test object, which is created using different spindle speeds of 4000, 6000, and 8000 RPM, as depicted in Figure 6.

Figure 6. Process of Cutting Objects.

Surface roughness measurement using the SRT-6223 surface profile gauge is carried out by calibrating the measuring instrument on the glass surface first, then the roughness measurement is carried out according to the specified procedure, including using the arithmetic average surface roughness parameter (Ra) using the formula (Institution, 1984):

$$N = ya+yb+yc+\ldots+yn/n \quad (1)$$

Where: N = Average measurement value (µm).
y = Measurement value (µm).
n = Total number of data.

After knowing the average measurement value, the next step is to find the absolute deviation value using the formula:

$$yi = y - N \quad (2)$$

Where: yi = Absolute deviation value (µm).

y = Measurement value (µm).

N = Average measurement value (µm).

After obtaining the absolute deviation value, the Ra value can be determined using the formula:

$$\mathrm{Ra} = \frac{1}{n}\sum_{i=1}^{n}|y_i| \quad (3)$$

Where: Ra = Arithmetic mean roughness value (µm).

yi = Absolute deviation value (µm).

n = Total number of data.

3. RESULT AND DISCUSSION

Result

Results are the main part of scientific articles, containing: final results without data analysis process, hypothesis testing results. Results can be presented with tables or graphs, to clarify the results verbally. The cutting process of each workpiece with varying spindle speeds has been carried out and produced the test pieces shown in Figure 7, Figure 8 and Figure 9.

Figure 7. Surface cutting results with a spindle speed of 4000 RPM

Figure 8. Surface cutting results with a spindle speed of 6000 RPM

Figure 9. Surface cutting results with a spindle speed of 8000 RPM

Based on the measurements of the surface roughness for each test object conducted with the Surface Profile Gauge SRT-6223 instrument, and using equations 1, 2, and 3 for calculations, the outcomes are presented in table 1, table 2, and table 3.

Tabel 1. Surface roughness of test object with spindle speed 4000 RPM.

Measurement point	Measurement Value (µm)	Deviation Value (µm)	Absolute Deviation Value (µm)
1	39,4	-12,52	12,52
2	15,5	-36,42	36,42
3	82	30,08	30,08
4	37,7	-14,22	14,22
5	63,5	11,58	11,58
6	13,2	-38,72	38,72
7	35,4	-16,52	16,52
8	74,5	22,58	22,58
9	81,1	29,18	29,18
10	76,9	24,98	24,98
Average	51,92	Ra (µm)	23,68

As seen in table 1, from 10 surface roughness measurement values of CNC router cutting results with a spindle speed of 4000 RPM, the average measurement value is 51.92 µm, and after calculating the absolute deviation, the arithmetic average roughness value (Ra) is 23.68 µm.

Tabel 2. Surface roughness of test object with spindle speed 6000 RPM.

Measurement point	Measurement Value (µm)	Deviation Value (µm)	Absolute Deviation Value (µm)
1	32,8	-7,45	7,45
2	73,8	33,55	33,55
3	19,5	-20,75	20,75
4	8,7	-31,55	31,55
5	48,8	8,55	8,55
6	24,1	-16,15	16,15
7	62	21,75	21,75
8	19,3	-20,95	20,95
9	80,5	40,25	40,25
10	33	-7,25	7,25
Average	40,25	Ra (µm)	20,82

Then, in table 2, it can be seen from 10 surface roughness measurement values of CNC router cutting results with a spindle speed of 6000 RPM, the average surface roughness measurement value is 40.25 µm and produces a Ra value of 20.82 µm.

Tabel 1. Surface roughness of test object with spindle speed 8000 RPM.

Measurement point	Measurement Value (µm)	Deviation Value (µm)	Absolute Deviation Value (µm)
1	82,4	-12,08	12,08
2	86,5	16,18	16,18
3	69,5	-0,82	0,82
4	62,6	-7,72	7,72
5	67,1	-3,22	3,22
6	54,2	-17,92	17,92
7	62	-8,32	8,32
8	66	-4,32	4,32
9	97	26,68	26,68
10	57,7	-12,63	12,63
Average	70,32	Ra (µm)	10,988

On the last test object, with a spindle speed of 8000 RPM as seen in table 3, the average of the 10 surface roughness measurement values is 70.32 µm and produces a Ra value of 10.988 µm.

Discussion

Comparison of surface roughness deviation values of 3 specimens with spindle speed variations can be seen in table 1, table 2, and table 3. The surface roughness deviation values at each measurement point have different values. As seen in table 1, specimens with a spindle speed of 4000 RPM tend to have higher deviation values compared to the other 2 specimens at each measurement point, and specimens with a spindle speed of 8000 RPM tend to have lower deviation values. Meanwhile, specimens with a spindle speed of 6000 RPM tend to have middle values between the other 2 specimens. In addition, the spindle speed parameter is inversely proportional to the Ra value, where the higher the spindle speed parameter, the lower the Ra value. The decrease in surface roughness value from the 4000 RPM specimen to 6000 RPM is 2.86 µm, and from the 6000 RPM specimen to 8000 RPM is 9.832 µm. Spindle speed variations have an effect on the surface roughness value of the workpiece with teak wood material, where the higher the spindle speed value, the lower the surface roughness value of the workpiece (Hidayatulloh et al., 2020; Roni Mustafik, 2020; Setyono et al., 2020; Thomas et al., 2023).

4. CONCLUSION

The results of the study of the surface roughness of teak wood test objects, the best arithmetic mean roughness value (Ra) or the smoothest workpiece surface from the spindle speed variation, was obtained on the workpiece using a spindle speed of 8000 RPM with a Ra value of 10.988 µm. Then a decrease in the surface roughness value was obtained from the 4000 RPM to 6000 RPM specimen of 2.86 µm, and from the 6000 RPM to 8000 RPM specimen of 9.832 µm. Variations in spindle speed affect the surface roughness value of objects made of teak wood, where the higher the spindle speed value, the lower the surface roughness value of the object.

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